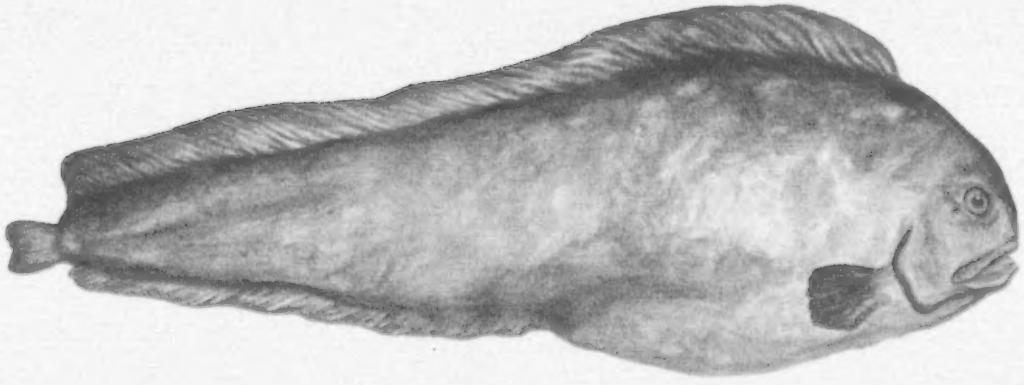
COSEWIC
Assessment and Status Report

on the

Northern Wolffish
Anarhichas denticulatus

in Canada



THREATENED
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
Northern Wolffish

Scientific name
Anarhichas denticulatus

Status
Threatened

Reason for designation
This species underwent strong declines in both abundance and in range size during the 1980s. For the next decade there was little change, but since about 2002 there have been small increases in both range size and abundance. These have been in parallel with recovery measures, including mandatory release of individuals taken as bycatch. While these recent increases are encouraging, the species is still at very low levels compared with the beginning of research surveys in the 1970s. Although there has been a general decrease in the level of fishing over its range, its recovery may still be limited by bycatch in fisheries in the deep waters in which it occurs.

Occurrence
Arctic Ocean, Atlantic Ocean

Status history
Designated Threatened in May 2001. Status re-examined and confirmed in November 2012.

COSEWIC
Executive Summary

Northern Wolffish
Anarhichas denticulatus

Wildlife Species Description and Significance

The Northern Wolffish, *Anarhichas denticulatus,* is a large elongate fish that can reach 180 cm in length. In common with all wolffishes, it has prominent teeth in the front of the jaws and flattened grinding teeth behind. It has a relatively smaller head than other wolffish species, with a greyish to dark brown body covered by indistinct dark bars or spots.

There are no indications of population structure that can be used to geographically distinguish Northern Wolffish. This species is therefore treated as a single designatable unit in Canadian waters.

Due to its gelatinous flesh, there is no commercial interest in this species. Catches were usually released by fishers even before it became mandatory to do so in 2003 under the *Species at Risk Act*.

Distribution

The Northern Wolffish inhabits boreal and subarctic waters on both sides of the North Atlantic and in the Arctic. In Canadian waters, it extends from the Canadian portion of the Gulf of Maine north to the Bay of Fundy, the Scotian Shelf, the Grand Banks, Gulf of St. Lawrence, Northeastern Newfoundland Shelf, and Labrador Sea as far as the waters west of Greenland. There are also a few records from the western Arctic. It is most abundant off northeastern Newfoundland and in the Labrador Sea.

Habitat

The eggs are probably deposited on the bottom, and the larvae and juveniles are thought to occupy the upper layer of the water column before subsequently settling to the bottom. Adults also spend time in the water column. This species occurs at greater depths than Atlantic or Spotted Wolffish and is mostly found between 500 and 1000 m. Prior to its decline, it was caught on all bottom types in Fisheries and Oceans Canada (DFO) research trawl surveys. It is now believed to be more common over sand and shell hash in the fall and over sand in the spring. Water temperature appears to be a major factor determining habitat selection in this species, which is most common at temperatures between 2 and 5°C.

Biology

The size and age at which 50% of females reach sexual maturity are estimated at 75 cm and 5.5 years, respectively. The generation time is estimated at 10.5 years. Spawning is thought to occur late in the year. Fertilization is internal and fecundity is low for a fish this size. Larvae likely feed on crustaceans and fish eggs and larvae. Adults generally undertake only limited movements, and feed primarily on pelagic fish, as well as jellyfish, echinoderms, crustaceans and molluscs. Juvenile wolffish have been found in the stomachs of seals, Atlantic Cod (*Gadus morhua*), Atlantic Halibut (*Hippoglossus hippoglossus*), and Haddock (*Melanogrammus aeglefinus*).

Population Sizes and Trends

Changes in Northern Wolffish abundance are monitored by DFO using research trawl surveys, which have been conducted for a number of years and cover a large portion of the species' Canadian range. The number of adults in Canadian waters is estimated at over 1 million. There has been steep decline in abundance in the central part of its range since the 1980s, especially in the Labrador Sea. There has been a small upward trend since 1996 in the Southern Labrador Shelf. In the Grand Banks and south coast of Newfoundland, some of the highest values since the start of the late 1990s have been recorded in several recent years. These fish are rare in the Gulf of St. Lawrence and in the southern part of its Canadian range.

Threats and Limiting Factors

Bycatch in fisheries is a threat to this species, though release of bycatch is mandatory and this species has no commercial value. Although the species is generally robust, it is unclear how well they survive when brought up from the deep waters they typically inhabit. This species has probably benefited from closure of many groundfish fisheries. It is also caught outside Canadian waters. While it is of little interest to foreign fishers, there is unreported bycatch mortality. Disturbance or alteration of the seabed by mobile fishing gear could threaten this species, though the severity of this threat is unknown. Climate change may also affect this species' abundance and distribution.

Protection, Status and Ranks

The Northern Wolffish was first assessed as Threatened by COSEWIC in May 2001, the status was confirmed in 2012 and the species has been protected under the federal *Species at Risk Act* since 2003. In addition, the federal *Fisheries Act* prohibits the destruction of habitats of fish that are targeted by fisheries. The species is also listed as likely to be designated threatened or vulnerable under Quebec's *Act Respecting Threatened or Vulnerable Species* (Loi sur les espèces menacées ou vulnérables; R.S.Q., c E-12.01). A very small fraction of this species' range occurs in Canada's marine protected areas network, and some areas are currently subject to a closure to bottom-trawling.

TECHNICAL SUMMARY

Anarhichas denticulatus
Northern Wolffish *Loup à tête large*
Range of occurrence in Canada: Eastern and Western Arctic Ocean and the Atlantic Ocean (including the Gulf of Maine, Scotian Shelf, Grand Banks, Gulf of St. Lawrence, Northeastern Newfoundland and Labrador Sea)

Demographic Information

Generation time (average age of parents in the population)	10.5 years
Is there an observed continuing decline in the number of mature individuals?	No
Estimated percent of continuing decline in the total number of mature individuals within 5 years or 2 generations	N/A
Estimated changes in the total number of mature individuals over the last 3 generations. True rate of decline not known due to changes in survey gear and regional variation in survey methods. There were strong declines in total number of fish (adults and immature combined) from the 1980s until the mid-1990s, and small increases over the past decade. Numbers remain very low compared to the start of the surveys.	Decline may exceed 90%
Projected percent change in the total number of mature individuals over the next 10 years, or 3 generations.	Unknown
Percent change in the total number of mature individuals over any 10 year or 3 generation period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and have in fact ceased?	Reduced but probably not ceased
Are there extreme fluctuations in the number of mature individuals?	Probably not

Extent and Occupancy Information

Estimated extent of occurrence within Canada's jurisdiction 2.221 million km² total including major land masses	1.628 million km² excluding major land masses
Index of area of occupancy (IAO) [Based on a 2 × 2 grid].	14 900 km²
Is the total population severely fragmented?	No
Number of locations* By-catch mortality in diverse fisheries occurs over a large region.	Multiple, but exact number unclear.
Is there a continuing decline in the extent of occurrence	No
Is there a continuing decline in the index of area of occupancy?	No
Is there a continuing decline in the number of populations?	No
Is there a continuing decline in the number of locations*?	No
Is there a continuing decline in the area, extent and/or quality of habitat?	No
Are there extreme fluctuations in the number of populations?	No
Are there extreme fluctuations in the number of locations*?	No
Are there extreme fluctuations in the extent of occurrence?	No
Are there extreme fluctuations in the index of area of occupancy?	Probably not

* See definition of "location."

Number of Mature Individuals (in each population)

Population	N mature individuals
Canadian	> 1 million

Quantitative Analysis

Probability of extinction in the wild is at least 20% within 20 years or 5 generations, or 10% within 100 years.	Analysis not done

Threats (actual or imminent, to populations or habitats)

Bycatch in commercial fisheries
Climate change (particularly water temperature)

Rescue Effect

Status of outside population(s)	Largely unknown
Is immigration known or possible?	Possible, but probably rare
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Possible from the east

Status History

Designated Threatened in May 2001. Status re-examined and confirmed in November 2012.

Status and Reasons for Designation

Status:	Alpha-numeric code:
Threatened	A2b

Reasons for designation:

This species underwent strong declines in both abundance and in range size during the 1980s. For the next decade there was little change, but since about 2002 there have been small increases in both range size and abundance. These have been in parallel with recovery measures, including mandatory release of individuals taken as bycatch. While these recent increases are encouraging, the species is still at very low levels compared with the beginning of research surveys in the 1970s. Although there has been a general decrease in the level of fishing over its range, its recovery may still be limited by bycatch in fisheries in the deep waters in which it occurs.

Applicability of Criteria

Criterion A:
Most data do not distinguish between adults and immature individuals, but data on the total number of individuals are available since the 1970s (Grand Banks) or 1980s (Southern Labrador Shelf). Overall declines meet the criterion for Endangered under A2b, but the species is designated Threatened A2b, because there have been small increases over most of the range since the early 2000s in both abundance and area of occupancy.

Criterion B:
Does not apply because the extent of occurrence greatly exceeds 20,000 km² and the area of occupancy greatly exceeds 2,000 km².

Criterion C:
Does not apply because the number of mature individuals greatly exceeds 10,000.

Criterion D:
Does not apply because the number of mature individuals greatly exceeds 1,000 and the area of occupancy is very large

Criterion E:
Not undertaken.

PREFACE

The Northern Wolffish (*Anarhichas denticulatus*) was assessed as threatened by COSEWIC in May 2001 and is on Schedule 1 of the *Species at Risk Act* (SARA) due primarily to the high rate of decline in abundance and the contraction of its range in the 1980s and 1990s. This report updates its status based on recent abundance and distribution data that have become available since the last assessment. Some new information on habitat has also been included.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Northern Wolffish

Anarhichas denticulatus

in Canada

2012

TABLE OF CONTENTS

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE 5
Name and Classification 5
Morphological Description 5
Population Variability and Spatial Structure 6
Designatable Units 7
Significance 7
DISTRIBUTION 7
Global Range 7
Search Effort 8
Canadian Range 11
Extent of Occurrence and Area of Occupancy 13
HABITAT 15
Habitat Requirements 15
Habitat Trends 16
Biology 17
Physiology and Adaptability 19
Dispersal and Migration 19
Interspecific Interactions 19
POPULATION SIZES AND TRENDS 20
Sampling Activities and Methods 20
Abundance 23
Fluctuations and Trends 24
Other areas (Gulf of St. Lawrence, Scotian Shelf, Arctic) 31
Summary for Canada 32
Rescue Effect 33
THREATS AND LIMITING FACTORS 34
Commercial Fishery and Bycatch 34
Environmental Factors 35
Number of Locations 35
PROTECTION, STATUS AND RANKS 36
Legal Status and Protection 36
Non-Legal Status and Ranks 36
Habitat Protection and Ownership 36
ACKNOWLEDGEMENTS AND AUTHORITIES CONSULTED 37
INFORMATION SOURCES 37
BIOGRAPHICAL SUMMARY OF REPORT WRITER 41

List of Figures

Figure 1. Northern Wolffish (*Anarhichas denticulatus*) and distinguishing morphological features. Photo credit: Carolyn Miri, Department of Fisheries and Oceans. .. 6
Figure 2. Potential global range of the Northern Wolffish. Source: Kaschner *et al.* (2008). 8
Figure 3. Map of geographic locations mentioned in this document. 9
Figure 4. Northwest Atlantic Fisheries Organization (NAFO) Subareas and Divisions. 10

Figure 5. Extent of occurrence of Northern Wolffish in Canadian waters. Note that this map does not include four records from the Western Arctic (see text)..... 12
Figure 6. Index of area of occupancy of the Northern Wolffish based on catches from various Fisheries and Oceans Canada research trawl surveys. Note that this map does not include four records from the Western Arctic (see text)..... 13
Figure 7. Index of area of occupancy (DWAO) of Northern Wolffish on the Grand Banks (3LNO) and in the Labrador Sea (2J3K) based on Newfoundland and Labrador fall research trawl surveys. The vertical line indicates a change in survey gear. Source: Mark Simpson, pers. comm. 2010. 14
Figure 8. Winter Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) indices with 1950-2000 as base period. Data presented are for the Jan-Feb-Mar winter period. Source: Yashayaev and Greenan (2011). 16
Figure 9. Length frequency of Northern Wolffish based on catch data from the Newfoundland & Labrador fall research trawl surveys from 1995 to 2001. Source: raw data provided by Mark Simpson, pers. comm., 2010..... 18
Figure 10. Northern Wolffish abundance (± CI) estimates based on Newfoundland and Labrador fall research trawl surveys for each NAFO Division covered. The vertical line indicates a gear change. Source: Simpson *et al.* (2011)..... 26
Figure 11. Northern Wolffish abundance estimates based on Newfoundland and Labrador fall research trawl surveys for NAFO Divisions 2J3KL from 1981 to 2009. The vertical line indicates a change in survey gear. Source: Mark Simpson, pers. comm., 2010. 27
Figure 12. Estimate of $\log_e$ abundance of Northern Wolffish based on Newfoundland and Labrador Fall research trawl surveys in NAFO Divisions 2J3KL from 1981 to 2009. The vertical line indicates a change in survey gear..... 28
Figure 13. Northern Wolffish abundance estimates (± CI) from the Grand Banks, based on Newfoundland and Labrador spring research trawl surveys for each NAFO Division covered from 1971 to 2010. The vertical lines indicate changes in survey gear. Note that there was an incomplete survey in 1983.29
Figure 14. Estimates of $\log_e$ abundance of Northern Wolffish based on Newfoundland & Labrador Spring research trawl surveys in NAFO Divisions 3LNOPs. The vertical lines indicate a change in survey gear..... 30
Figure 15. Relative occurrence (number of tows in which the species is present/total number of tows) of Northern Wolffish (all ages combined) in research trawl surveys in the northern and southern Gulf of St. Lawrence (NAFO Divisions 4RST). 32
Figure 16. Northern Wolffish abundance estimates (all ages combined) for the Flemish Cap (NAFO Division 3M) based on research trawl surveys conducted by the Instituto Español de Oceanografía (Spanish Institute of Oceanography). Source: Based on Gonzalez-Troncoso and Paz (2007)..... 34

List of Tables

Table 1. Information sources used to determine the distribution of the Northern Wolffish in Canadian waters. 8

Table 2. Description of research surveys used in this report to determine Northern Wolffish abundance trends. 20

Table 3. NAFO Divisions and Subdivisions sampled by Fisheries and Oceans Canada Newfoundland and Labrador Region spring and fall research trawl surveys (dark boxes indicate that a survey was conducted; white boxes indicate no survey). 21

Table 4. Minimum trawlable abundance of Northern Wolffish (total and mature populations) in each NAFO Division based on DFO research trawl surveys. Individuals > 75 cm total length are considered mature. 23

Table 5. Northern Wolffish abundance (total population) indices based on Newfoundland and Labrador fall research trawl survey data. 24

Table 6. Rates of change in Northern Wolffish abundance indices based on research trawl survey data. 25

Table 7. Northern Wolffish abundance indices based on Newfoundland & Labrador spring research trawl survey data. 30

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Actinopterygii

Order: Perciformes

Family: Anarhichadidae

Scientific name: *Anarhichas denticulatus* (Krøyer 1845)

Common name: English – Northern Wolffish
Also: Broadhead Wolffish, Blue Sea Cat, Jelly-Cat
French – Loup à tête large
Also: Loup gélatineux (France)

Morphological Description

Fish of the family Anarhichadidae are large marine fish that get their name from their large, conical teeth. There are three species of wolffish in the Canadian Atlantic: Northern Wolffish (*Anarhichas denticulatus)*, which is the subject of this report, Atlantic Wolffish (*Anarhichas lupus*), and Spotted Wolffish (*A. minor*).

The Northern Wolffish (Figure 1) is a large fish with a relatively small head, compared to other wolffish species, a blunt snout, small eyes, and small pectoral fins. In common with all wolffishes, it has prominent teeth in front of the jaws and flattened grinding (vomerine) teeth behind. It can reach 180 cm in length (Robins and Ray 1986). It ranges from greyish to dark chocolate with a light violet sheen and often has numerous but indistinct dark bars or spots on its body. There are no pelvic fins.

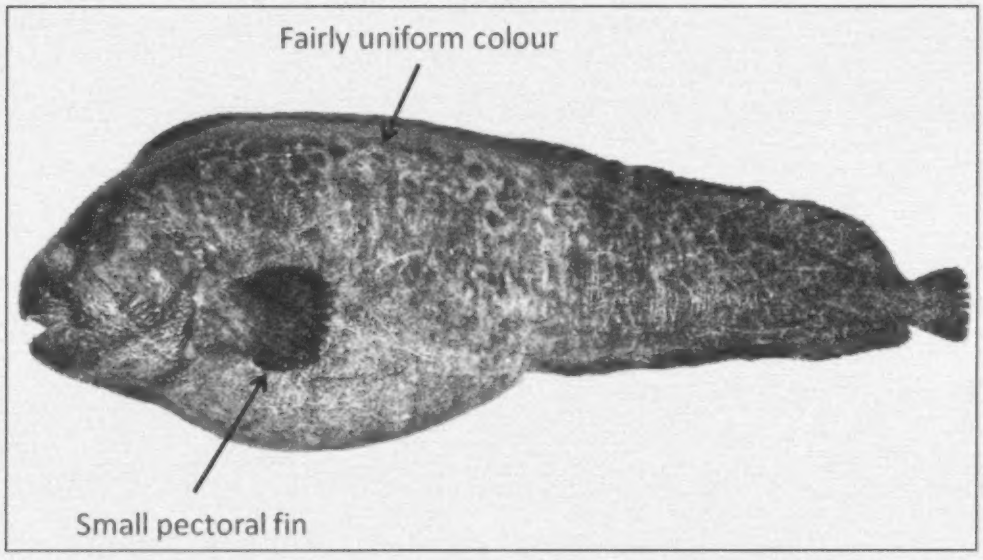

Figure 1. Northern Wolffish (*Anarhichas denticulatus*) and distinguishing morphological features. Photo credit: Carolyn Miri, Department of Fisheries and Oceans.

The Northern Wolffish is distinguished from other wolffish primarily by its jelly-like musculature. It is also more stout and deep-bodied at the abdomen and its body is generally more uniform in colour than the Atlantic Wolffish (with vertical bars) or Spotted Wolffish (with spots). The position of the vomerine teeth relative to the palatine teeth distinguishes the three wolffish species. The grinding teeth on the vomer do not extend as far back in the mouth as the palatine teeth do. In Atlantic Wolffish they extend farther back than the palatine teeth, and in Spotted Wolffish they extend as far back as the palatine teeth (Kulka *et al.* 2007b). In Northern Wolffish, the teeth are also smaller and sharper and do not wear down as quickly.

Population Variability and Spatial Structure

Little is known about the biology of the Northern Wolffish. However, if its life cycle and habits are similar to those of the Atlantic Wolffish, then dispersal by eggs is not possible because they are deposited on the substrate (O'Dea and Haedrich 2001). Dispersal can occur at the larval and early juvenile stage when they are in the water column. There is evidence juveniles (up to ~ 20 cm) are pelagic, unlike other wolffish species. Little information is available on the population structure of this species.

Genetic differences among the three species of wolffish of the northwestern Atlantic Ocean were evaluated on the basis of their mitochondrial DNA genomes (Johnstone *et al.* 2007, McCusker and Bentzen 2010) and nuclear genetic markers (McCusker *et al.* 2008, McCusker and Bentzen 2010). These studies showed that the three wolffish species in the Atlantic are distinct from each other, with the Northern Wolffish less related to the other two.

McCusker and Bentzen (2011) used nuclear microsatellites and amplified fragment length polymorphisms (AFLP) to study the population genetic structure of Northern Wolffish across the range of the species. Genetic differentiation was significant (F_{ST} = 0.012-0.032) between Atlantic Canada and the Barents Sea, but not between northern and southern regions of Atlantic Canada.

Designatable Units

The limited data available (McCusker and Bentzen 2011) provide no evidence of population structuring in Atlantic Canada. Therefore, in this status report, the species is treated as a single designatable unit in Canadian waters.

Significance

There is no commercial interest in the Northern Wolffish due to its gelatinous flesh. It may occasionally be consumed by Greenlanders (COSEWIC unpubl. report *in* Kulka *et al.* 2007a). Similarly, its skin is not suitable for secondary processing, unlike the case with Atlantic and Spotted Wolffish. Northern Wolffish catches are almost always released by fishers. Since 2003, moreover, its release has been mandatory due to its threatened status under the *Species at Risk Act* (SARA).

The ecological role of the Northern Wolffish is difficult to assess owing to lack of information.

DISTRIBUTION

Global Range

Northern Wolffish inhabit cold waters (boreal, Arctic and subarctic). They occur from Iceland and the Faroe Islands to the waters of Norway and the Barents Sea (Figure 2) (Whitehead *et al.* 1986). In the northwestern Atlantic and Canadian Arctic, its range extends from Baffin Bay to the Gulf of Maine and includes the Labrador and northeast Newfoundland Shelves, the Grand Banks, the Flemish Cap, the Gulf of St. Lawrence and the Scotian Shelf. It has also been reported from the western Arctic (see "Canadian Range", below). Figure 3 shows the geographic locations of areas mentioned in this report.

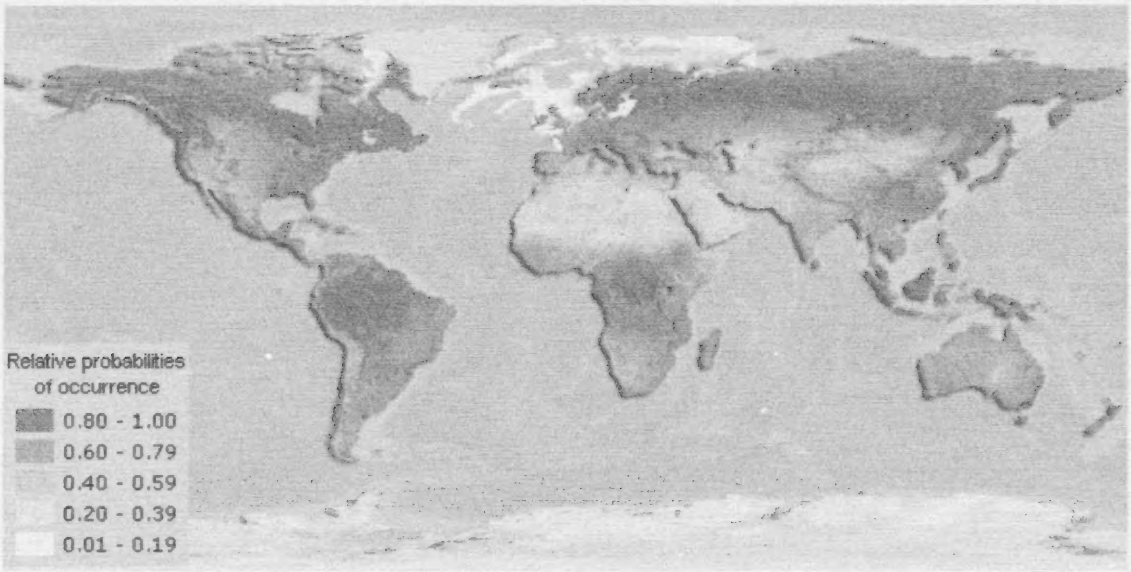

Figure 2. Potential global range of the Northern Wolffish. Source: Kaschner *et al.* (2008).

Search Effort

Table 1 shows the main surveys used to determine the distribution of the Northern Wolffish in Canadian waters. Most of the information is from DFO research trawl surveys, which are described in detail under "Population Sizes and Trends". These surveys, some of which have been conducted for over 40 years, use a stratified random sampling protocol. They cover a large range of demersal species in Canada, as well as some international areas. Figure 3 shows the locations of the areas mentioned in this report, and Figure 4 shows the NAFO Divisions.

Table 1. Information sources used to determine the distribution of the Northern Wolffish in Canadian waters.

Regions	Information source
Newfoundland and Labrador (Labrador Shelf, northeastern and southern Newfoundland)	Fisheries and Oceans Canada spring research trawl survey
	Fisheries and Oceans Canada fall research trawl survey
Gulf of St. Lawrence	Fisheries and Oceans Canada Northern Gulf research trawl survey
	Fisheries and Oceans Canada Southern Gulf research trawl survey
	Sentinel Fisheries Program
Maritimes (Scotian Shelf, Bay of Fundy, Gulf of Maine)	Fisheries and Oceans Canada Maritimes summer research trawl survey
Central and Arctic	Fisheries and Oceans Canada research trawl survey

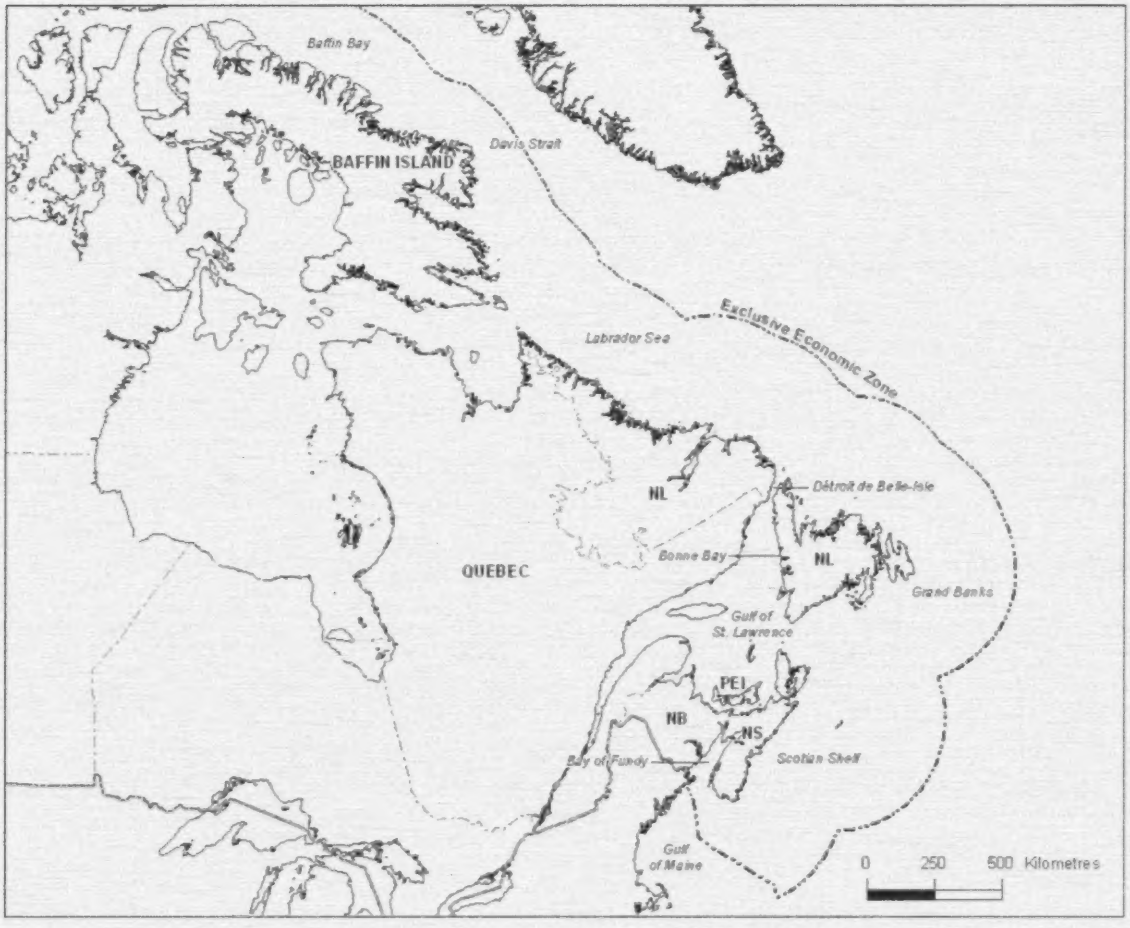

Figure 3. Map of geographic locations mentioned in this document.

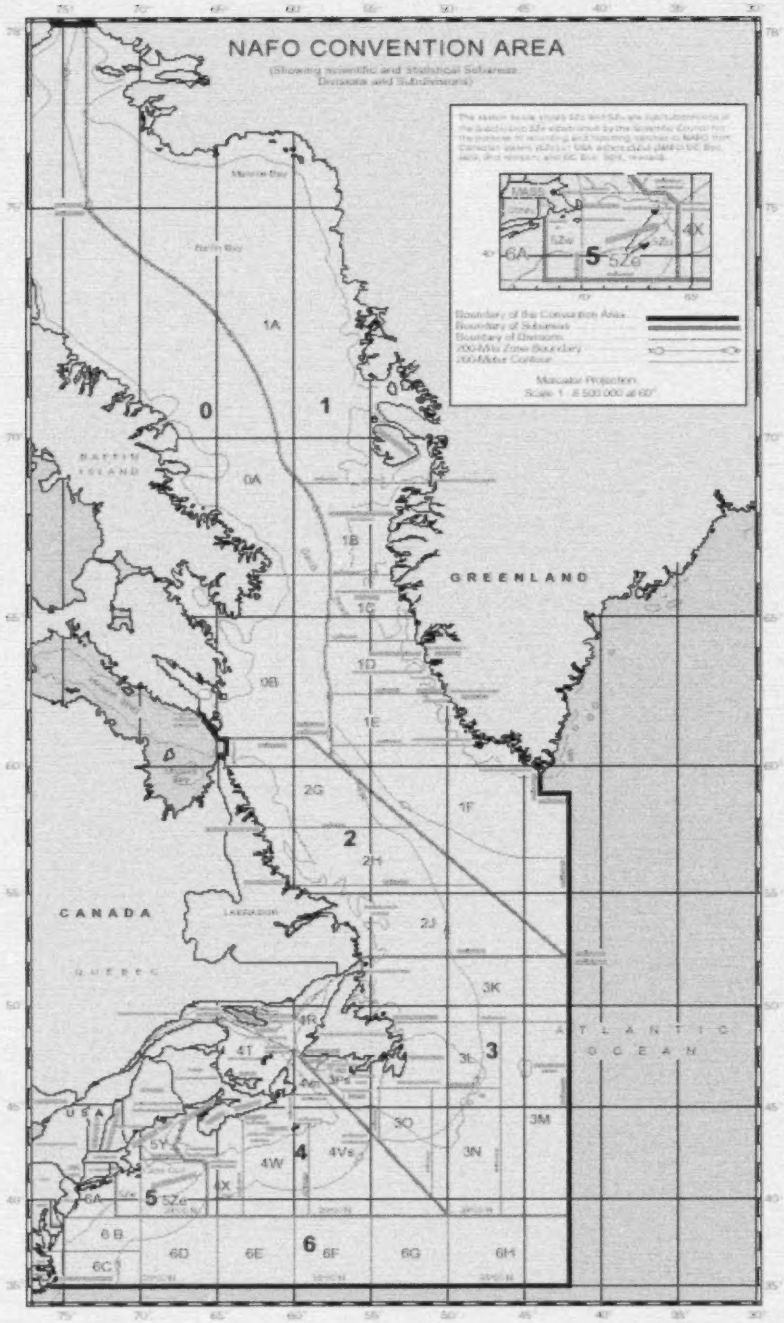

Figure 4. Northwest Atlantic Fisheries Organization (NAFO) Subareas and Divisions.

Most areas are well covered except rocky areas and areas close to shore, due to the high risk of gear damage. The survey time series is relatively short for areas near the northern limit of the range of the Northern Wolffish (NAFO Subarea 0). Surveys were conducted by DFO in Baffin Bay (NAFO Division 0A) in 1999, 2001, 2004, 2006, and 2008 and in Davis Strait (Division 0B) in 2000 and 2001.

In recent years, additional surveys in which wolffish are likely to be caught have also been conducted by DFO in collaboration with industry. The Canadian At-Sea Fisheries Observer Program is a source of information on the distribution of marine fish species and composition of commercial catches but the data are not directly comparable to DFO's research trawl surveys and are therefore not included here. The Groundfish Sentinel Program conducts mobile gear surveys (bottom trawl) and fixed gear surveys (longline and gill net). Redfish (*Sebastes spp.*) and Atlantic Halibut (*Hippoglossus hippoglossus*) surveys are conducted in collaboration with the Groundfish Enterprise Allocation Council (GEAC) and Northern Shrimp surveys are conducted in collaboration with the Northern Shrimp Research Foundation.

Canadian Range

In Canadian waters, the Northern Wolffish occurs off Baffin Island and in the Labrador Sea, the Gulf of St. Lawrence, the Grand Banks and the Scotian Shelf (Figure 5). The data in Figure 5 are from DFO research vessel surveys. The species' range probably extends further north than indicated on the map, as suggested by reports from the Canadian At-Sea Fisheries Observer Program (commercial fisheries). These reports are not directly comparable to the data from the research trawl surveys and are therefore not included here. The central part of its range is on the Labrador Shelf and off northeastern Newfoundland (Kulka *et al.* 2007a, Simpson *et al.* 2011).

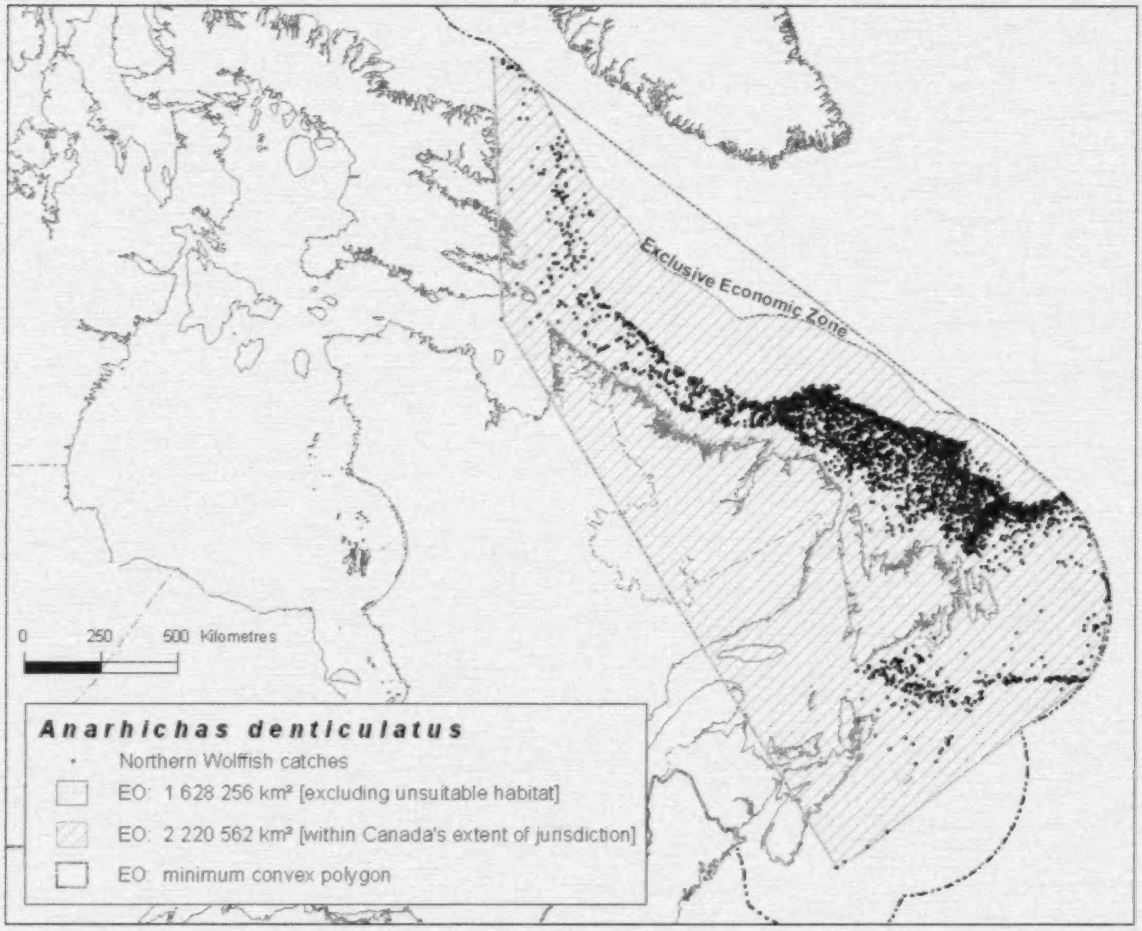
Exclusive Economic Zone
0 250 500 Kilometres
Anarhichas denticulatus
Northern Wolffish catches
EO: 1 628 256 km² [excluding unsuitable habitat]
EO: 2 220 562 km² [within Canada's extent of jurisdiction]
EO: minimum convex polygon

Figure 5. Extent of occurrence of Northern Wolffish in Canadian waters. Note that this map does not include four records from the Western Arctic (see text).

This species is most abundant in the deep waters of the continental shelf, off northeastern Newfoundland and on the Labrador Shelf and to a lesser extent along the shelf edge of the Grand Bank. It is only occasionally observed in the Gulf of St. Lawrence, on the Scotian Shelf, in the Gulf of Maine, the Bay of Fundy, Baffin Bay and Davis Strait. There are also four verified records from the western Arctic (Noel Alfonso, Canadian Museum of Nature, pers. comm. 2012). This suggests the possibility that the range could extend right across the Arctic, though more surveys are needed to verify this.

Extent of Occurrence and Area of Occupancy

Distribution indices were calculated by the COSEWIC Secretariat. The extent of occurrence was determined by calculating the area of the minimum convex polygon encompassing all sites covered by the research trawl surveys (Figure 5). The extent of occurrence is estimated at 2.221×10^6 km^2. However, this estimate includes some major landmasses. When these are excluded, the value is 1.628×10^6 km^2.

An index of area of occupancy was calculated using kriging based on a grid with a cell size of 2 km × 2 km over the entire area occupied by the species in Canada (Figure 6). This index is estimated at 14,900 km^2.

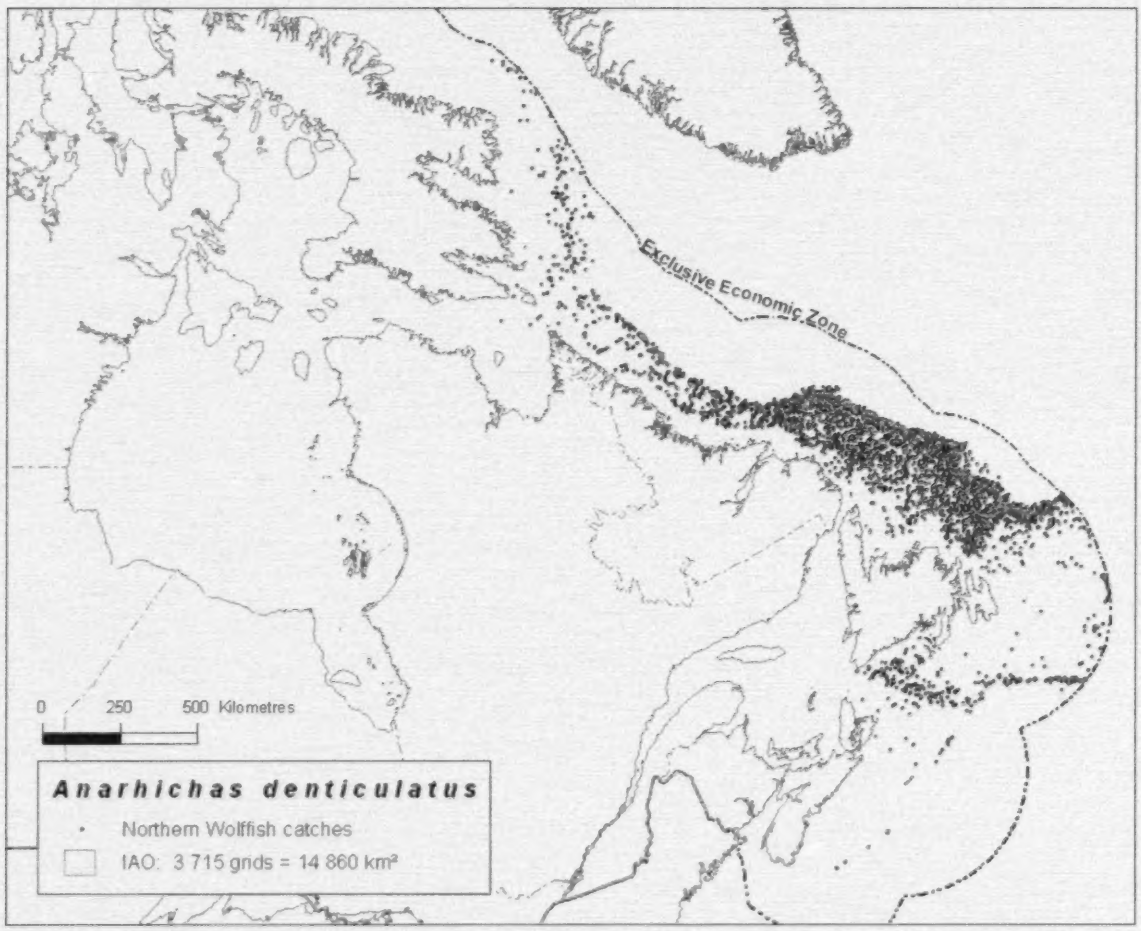

Figure 6. Index of area of occupancy of the Northern Wolffish based on catches from various Fisheries and Oceans Canada research trawl surveys. Note that this map does not include four records from the Western Arctic (see text).

The design-weighted area of occupancy (DWAO) index was calculated for the Newfoundland region:

$$A_t = \sum_{i=1}^{n} A_i I \text{ where } I = 1 \text{ if } Y_i > 0, 0 \text{ otherwise,}$$

where n is the number of tows in the survey, Y_i is the number of individuals caught in tow i, and A_i is the area of the stratum fished by tow i divided by the number of sites fished in the stratum.

The DWAO index obtained from the Newfoundland fall trawl surveys declined sharply from the 1980s to 1990. However, it has increased since the early 2000s but it is still much smaller than previously (Figure 7). The decline was most significant in the Labrador Sea and off northeastern Newfoundland (NAFO Divisions 2J3K). It is important to bear in mind that due to gear changes, different data series values cannot be compared directly.

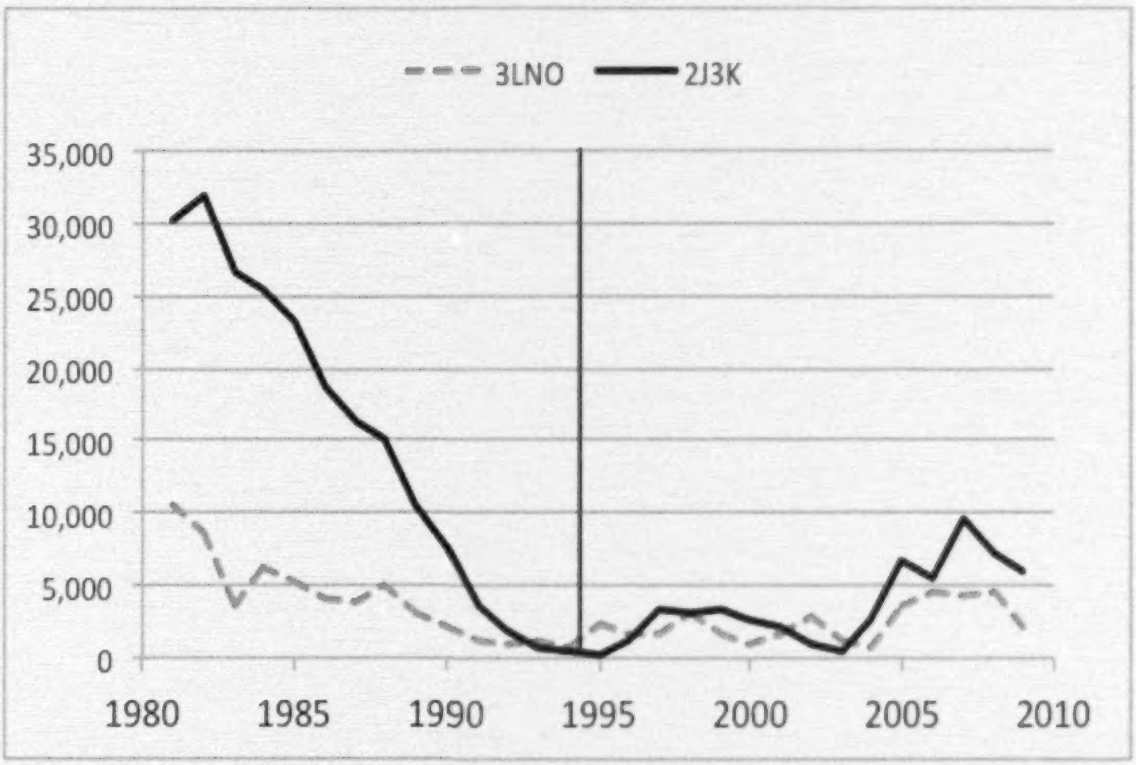

Figure 7. Index of area of occupancy (DWAO) of Northern Wolffish on the Grand Banks (3LNO) and in the Labrador Sea (2J3K) based on Newfoundland and Labrador fall research trawl surveys. The vertical line indicates a change in survey gear. Source: Mark Simpson, pers. comm. 2010.

HABITAT

Habitat Requirements

Little is known about Northern Wolffish habitat, given the species is of no commercial value and inhabits deep areas. Its habitat requirements have been extrapolated from sites where it was caught in DFO research trawl surveys in the central part of its range (northeastern Newfoundland and Labrador Sea). In addition, information from Atlantic and Spotted Wolffish may be relevant, though this would have to be validated.

The Northern Wolffish occupies different habitats depending on its life stage. Eggs are probably deposited on the bottom, based on observations of the closely related Atlantic Wolffish. The larvae and young of the year occupy the upper water column before settling on the bottom. Juvenile Spotted Wolffish use refuges (Lachance *et al.* 2010). This could also be true for Northern Wolffish but the species is more pelagic than the other two wolffish species, with adults spending time in the water column (Templeman 1984, Shevelev and Kuz'michev 1990).

Of the three species of wolffish in the northwest Atlantic, the Northern Wolffish occurs at the greatest depths (Kulka *et al*, 2004, 2007), with adults found between 38-1504 m, but mainly between 500 and 1000 m. Some shift toward shallower water (200-350 m) has been observed from June to November, and higher depth ranges have been observed during periods of high abundance (Kulka *et al.* 2004).

The Northern Wolffish is a cool water fish, with the highest densities at temperatures between 2 and 5°C (Kulka *et al.* 2004). On the Scotian Shelf, most of the population is found in a narrow temperature range of 3-5°C (Simon *et al.* 2011). Temperature is believed to limit their distribution and habitats (Kulka *et al.* 2004).

Before the decline in abundance, this species was caught in all types of substrate in DFO research trawl surveys (Newfoundland and Labrador). Since then, it is believed to occur more often over sand and shell hash (Kulka *et al.* 2004; 2007). It might be less frequently encountered over mud or muddy sediment in periods of low abundance (Kulka *et al.* 2004).

Habitat Trends

A period of exceptionally cold water temperatures was recorded in the late 1980s and early 1990s (Colbourne *et al.* 1997). Figure 8 shows the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) from 1950 to 2010 (Yashayaev and Greenan 2011). A positive index is associated with colder than usual conditions in the northern Labrador Sea. The index for the end of 1980 to mid-1990 showed higher values since 1950. It has been suggested that this cold episode coincided with the rapid contraction in the range of wolffish species (Kulka *et al.* 2004), but most declines began a decade earlier (e.g., see "Population Sizes and Trends"). Shallower waters may have been abandoned by these species, possibly in favour of deeper, warmer waters. However, this possibility remains hypothetical.

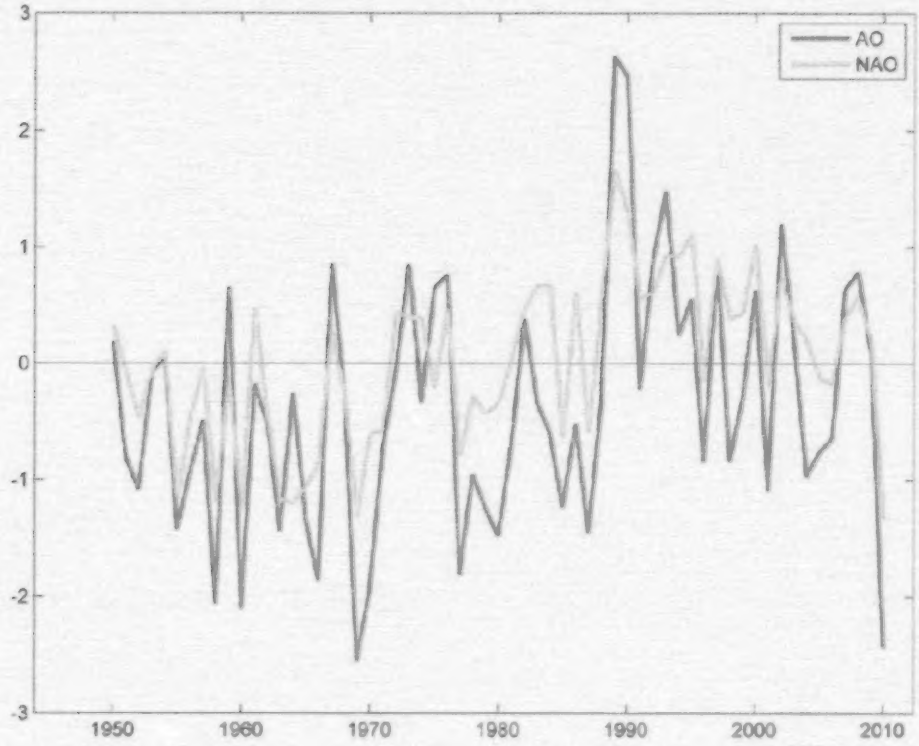

Figure 8. Winter Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) indices with 1950-2000 as base period. Data presented are for the Jan-Feb-Mar winter period. Source: Yashayaev and Greenan (2011).

The long-term trend in water temperature is uncertain. Climate change will likely affect the habitat and distribution of the Northern Wolffish. An increase in water temperatures in the northwest Atlantic may lead to a northward shift of many marine cold-water fish species such as this one (Gucinski *et al.* 1990), as has been documented in the northeastern Atlantic (Perry *et al.* 2005).

Biology

The biology of all three wolffish species is summarized in Kulka *et al.* (2007) and Simpson *et al.* (2011). There is no information on sexual maturation in the Northern Wolffish in the northwest Atlantic. However, the length (L50) and age (A50) at which 50% of females reach sexual maturity can be estimated from various growth parameters. An L50 of 75.2 cm and an A50 of 5.8 years are reported in Fishbase (Froese and Pauly, 2011). Simpson *et al.* (2011) also suggest an A50 between 5 and 6 years. These are rough estimates.

Spawning is thought to occur late in the year (Kulka *et al.* 2007a). Fertilization is internal (Falk-Petersen and Hansen 1994). The species is iteroparous and females have low fecundity compared to many teleost fishes of comparable size. An egg count of approximately 23 000 was obtained for females between 112 and 134 cm in length from the Barents Sea (Barsukov 1959 *in* Kulka *et al.* 2007a). Egg survival may be high due to their large size (between 7.2 and 8.0 mm in diameter according to Barsukov 1959 *in* Kulka *et al.* 2007a). Newly hatched larvae are 25-26 mm long (Shevelev and Kuz'michev 1990). They likely remain pelagic before settling on the bottom.

The growth rate of Northern Wolffish in the Canadian Atlantic is unknown and little information is available for other regions. Growth is probably rapid in the initial years of life, slowing when energy is diverted to gonad development. The maximum reported size is 180 cm (Robins and Ray 1986), and fish > 125 cm are rare (see Figure 9).

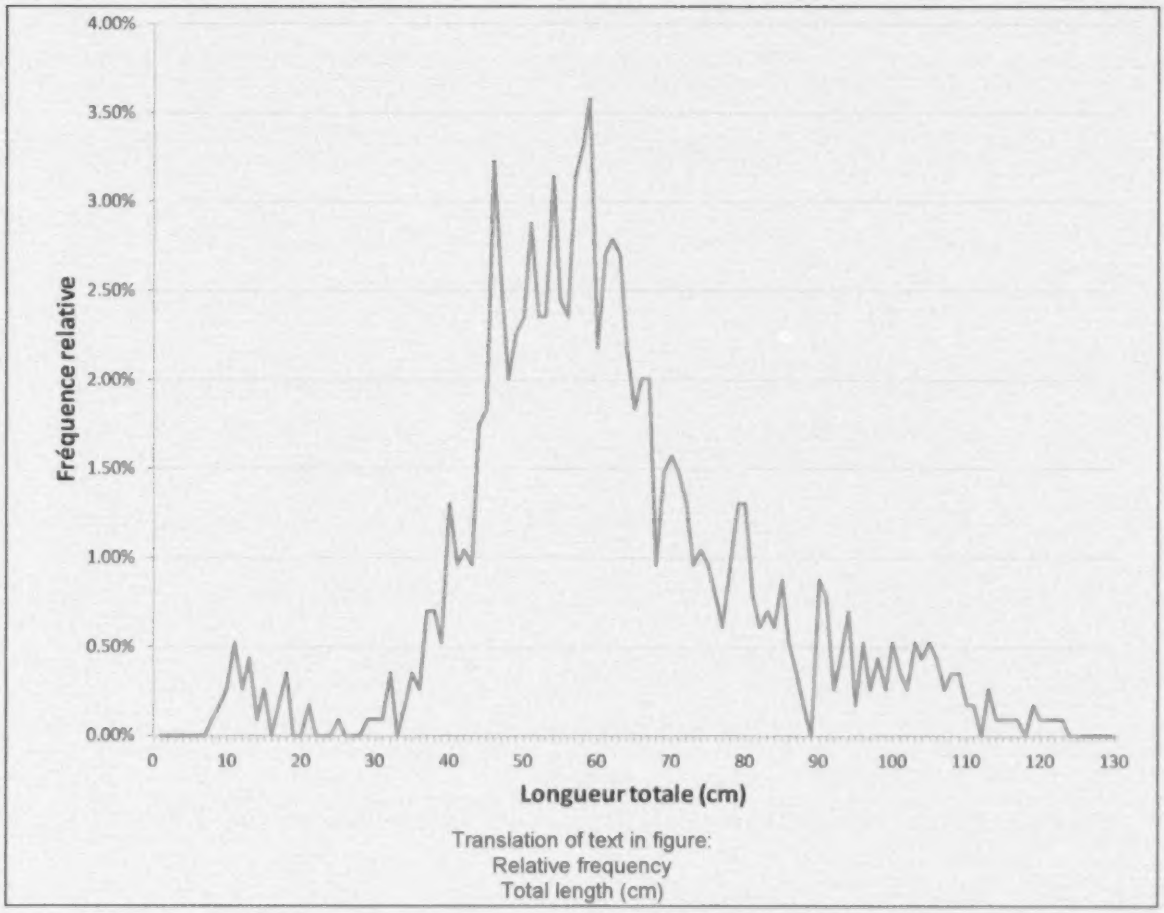

Figure 9. Length frequency of Northern Wolffish based on catch data from the Newfoundland & Labrador fall research trawl surveys from 1995 to 2001. Source: raw data provided by Mark Simpson, pers. comm., 2010.

No studies have been conducted on the natural mortality rate of the Northern Wolffish.

Generation time is defined by COSEWIC as the average age of parents of the current cohort:

$$G = A + 1/M,$$

where A is age at 50% maturity for females and M is the rate of natural mortality. A value of A of around 5.5 years has been reported above and an assumed M value for a fish that can reach a maximum age around 20 years would generally be 0.2. Generation time would then be roughly 10.5 years.

Physiology and Adaptability

The Northern Wolffish is a cool- to cold-water species and tolerates a range of water temperatures (-1 to 6.3°C) (Beese and Kandler 1969 *in* Kulka *et al.* 2007a). It is most abundant at a relatively narrow temperature range of 2-5°C off Newfoundland and Labrador (Kulka *et al.* 2004).

Dispersal and Migration

Templeman (1984) reported the results of a tagging study conducted between 1962 and 1966 on the three species of wolffish in waters off Newfoundland and Labrador. A total of 101 Northern Wolffish were tagged, but only 3 fish were recaptured. As with the other wolffish species, most were recaptured within a short distance of the original tagging site (approximately 8 km on average, all wolffish species combined). Other studies in the eastern Atlantic (several studies cited in Templeman 1984) and off west Greenland (Riget and Messtorff 1988) confirm that wolffish (Atlantic and Spotted) generally undertake only short migrations, though some migrations over distances of over 800 km have been observed occasionally in the Northwest Atlantic (Templeman 1984).

Interspecific Interactions

Northern Wolffish are thought to feed primarily on pelagic fish and invertebrates (Kulka *et al.* 2007a), indicating time spent in the water column, unlike the other two species of wolffish. Members of the family Anarhichadidae also feed on jellyfish, echinoderms, crustaceans and mollusks (Barsukov 1986). Recent data also indicate the importance of fish and gelatinous zooplankton (Simpson *et al.* 2011). Larvae probably eat crustaceans, fish eggs and fish larvae (Barsukov 1959).

There is little information on the predators of Northern Wolffish. However, juvenile wolffish have been found in the stomachs of Harbour Seals, *Phoca vitulina* (Andersen *et al.* 2004). Although wolffish generally account for only a small fraction of the diet of seals, it is estimated that four seal species – Harp (*Phagophilus groenlandicus*), Hooded (*Cystophora cristata*), Grey (*Halichoerus grypus*), and Harbour – consumed close to 6000 t of wolffish in 1996 in the Canadian Atlantic (Hammill and Stenson 2000). Of these, the Harp Seal is the most significant predator because of its high abundance. Wolffish have also been observed in the stomachs of Atlantic Cod (Saemundsson 1949 *in* McRuer *et al.* 2000), Atlantic Halibut (Chabot pers. comm. 2010), Haddock, and Thorny Skate (*Amblyraja radiata*) (Simon *et al.* 2011).

POPULATION SIZES AND TRENDS

Sampling Activities and Methods

Changes in Northern Wolffish abundance were assessed from DFO research trawl surveys, which were designed to assess the abundance of several groundfish species. A description of the surveys is presented in Table 2.

Table 2. Description of research surveys used in this report to determine Northern Wolffish abundance trends.

Survey	NAFO Division	Year	Gear
Fisheries and Oceans Canada research trawl surveys			
Summer surveys (Maritimes)	4V, 4W and 4X	1970–1981	Yankee 36 trawl
		1982 to present	Western IIA trawl
Northern Gulf surveys	4RS and deep areas of 4T	1990–2003	URI 81'/114' trawl
		2004 to date	Campelen trawl
Southern Gulf surveys	4T	1971–1985	Yankee trawl
		1986 to present	Western IIA trawl
Spring surveys (Newfoundland & Labrador)	3N, 3O, 3Ps and 3L	1971–1982	Yankee 41.5 trawl
		1983–1995	Engel trawl
		1996 to present	Campelen trawl
Fall surveys (Newfoundland & Labrador)	2G, 2H, 3N, 3O, 3K and 3L	1977–1994	Engel trawl
		1995 to present	Campelen trawl

Details of Canadian surveys are described in Kulka *et al.* (2006). They cover a large range of demersal species in Canada (and even certain international areas in the Grand Banks, 3LNO). Most areas are well covered except coastal areas and a portion of the regions at or near the northern limit of the range of the Northern Wolffish (NAFO Subarea 0). Surveys were also conducted by DFO in Baffin Bay (NAFO Subarea 0A) in 1999, 2001, 2004, 2006, and 2008 and in Davis Strait (Subarea 0B) in 2000 and 2001. The data from these were too limited to support analyses.

Results from the Newfoundland and Labrador Region surveys in NAFO Subareas 2 and 3 are presented in the form of "minimum trawlable abundance" estimates. These estimates underestimate the actual abundance of the population because the fishing gear does not capture all fish in the trawl path. Some fish may avoid or escape from the trawl or may occur in areas unreachable by the trawl (e.g., rough grounds, very deep areas, and the water column above the path of the gear).

According to the size frequency of catches in the Newfoundland fall research trawl survey (Figure 9), most of the captured fish are 45-75 cm in length, i.e. immature fish, although fish up to 120 cm are not uncommon.

DFO's Newfoundland and Labrador Region has conducted spring and fall research trawl surveys on the Newfoundland Grand Banks and in the Labrador Sea since the early 1970s. Vessel and gear changes have occurred over the course of the surveys (Table 2). The most significant change was the conversion to Campelen shrimp gear from the Engel trawl in 1995. This latter gear probably has higher catchability, especially of small fish. In addition, the area covered has varied in some locations. Table 3 indicates the NAFO Divisions covered by surveys from 1971 to 2010 in these regions.

Table 3. NAFO Divisions and Subdivisions sampled by Fisheries and Oceans Canada Newfoundland and Labrador Region spring and fall research trawl surveys (dark boxes indicate that a survey was conducted; white boxes indicate no survey).

Year	NAFO Division										
	Fall research trawl survey							Spring research trawl survey			
	2G	2H	2J	3K	3L	3N	3O	3L	3N	3O	3Ps
1971								■	■	■	
1972								■	■		■
1973								■	■	■	■
1974								■	■		■
1975								■	■	■	■
1976								■	■	■	■
1977			■	■				■	■	■	■
1978	■	■	■	■				■	■	■	■
1979	■	■	■	■				■	■	■	■
1980			■	■				■	■	■	■
1981	■	■	■	■	■			■	■	■	■
1982			■	■	■			■	■	■	■
1983			■	■	■						■
1984			■	■	■			■	■	■	■
1985			■	■	■			■	■	■	■
1986			■	■	■			■	■	■	■
1987	■	■	■	■	■			■	■	■	■
1988	■	■	■	■	■			■	■	■	■

Year	NAFO Division										
	Fall research trawl survey							Spring research trawl survey			
	2G	2H	2J	3K	3L	3N	3O	3L	3N	3O	3Ps
1989											
1990											
1991											
1992											
1993											
1994											
1995											
1996											
1997											
1998											
1999											
2000											
2001											
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2006											
2007											
2008											
2009											
2010											

The research trawl surveys began in 1970 in the regions of the Scotian Shelf and Bay of Fundy (NAFO Divisions 4VWX, Maritimes summer research trawl surveys). There was a gear change in 1982 (the Yankee 36 was replaced by the Western IIa trawl). This change can potentially affect Northern Wolffish catch rates and size composition.

Two research trawl surveys are conducted in the Gulf of St. Lawrence, one covering Divisions 4R, 4S and the Esquiman Channel in Division 4T (northern Gulf research trawl survey) and the other in all of Division 4T (southern Gulf research trawl survey). For the northern Gulf research trawl survey, the vessel CCGS *Alfred Needler* equipped with a URI 81'/114' bottom trawl was used from 1990 to 2003. It was replaced by the CCGS *Teleost* equipped with a Campelen shrimp trawl. In the southern Gulf, the research trawl survey has been conducted in September since 1971. A gear change from the Yankee 36 to the Western IIA occurred in 1985.

Abundance

Minimum abundance can be estimated from DFO research trawl survey data (Table 4). The number of Northern Wolffish in Canadian waters is estimated at > 2.5 million. This is a conservative estimate, given that the surveys do not catch all individuals in the trawled area and abundance estimates are not available for certain low-abundance regions, such as the Gulf of St. Lawrence and Canadian Arctic. The adult Northern Wolffish population is believed to exceed 1 million (see Table 4 for details on evaluation years and areas).

Table 4. Minimum trawlable abundance of Northern Wolffish (total and mature populations) in each NAFO Division based on DFO research trawl surveys. Individuals ≥ 75 cm total length are considered mature.

NAFO Division	Total Abundance[1] (millions)	Abundance of Mature Individuals	Survey
2G	0.152[2] (1999)	0.062	Newfoundland & Labrador fall survey
2H	0.042[2] (2008)	0.008	
2J	0.702[2] (2009)	0.287	
3K	0.642[2] (2009)	0.262	
3L	0.522[2] (2009)	0.213	
3N	0.402[2] (2009)	0.164	
3O	0.042[2] (2009)	0.016	
3Ps	0.032 (2010)	0.004	Newfoundland & Labrador spring survey
4VWX	Marginal[4]	Marginal[4]	Maritimes summer survey
4RST	Marginal[4]	Marginal[4]	Northern Gulf survey
Total	2.5	1.0	

[1] The year of the most recent assessment is in parentheses.
[2] Simpson *et al.* 2011.
[4] Abundance was not calculated by DFO due to its low occurrence in research trawl surveys (Simon *et al.* 2011).

Fluctuations and Trends

Labrador Sea, eastern Newfoundland, Newfoundland Grand Banks and southern Newfoundland

Most Northern Wolffish in Canada are in the Labrador Sea and off eastern Newfoundland (Kulka *et al.* 2004). Trends there are therefore largely indicative of the status of the species. Abundance indices from fall research trawl survey data have declined since the 1980s throughout the study area (NAFO Divisions 2GHJ3KL: Labrador Sea, eastern Newfoundland and northern Newfoundland Grand Banks) (Table 5, Figure 10). The decline was greatest in Division 2J, which had the highest abundance in the early 1980s: indices fell from 10.46 million in 1977 to 0.03 million in 1994. Moreover, there were no catches of this species in 1995. However, since 1996, there has been a small upward trend. Figure 11 shows the total abundance in NAFO Divisions 2J3KL, which have been surveyed systematically since 1981. The abundance indices decreased from 9 million in 1981 to 0.21 million in 1994 (Table 5). This represents a 99% decline (Table 6, Figure 12). The abundance indices increased since then, rising from 1.0 million to 1.86 million from 1996 to 2009 (increase of 324%, Table 6). The change to the Campelen trawl in the fall survey starting in 1995 and in the spring survey in 1996 precludes direct comparison of the time series before and after the gear change.

Table 5. Northern Wolffish abundance (total population) indices based on Newfoundland and Labrador fall research trawl survey data.

YEAR	ABUNDANCE INDEX (MILLIONS)*							
	2G	2H	2J	3K	3L	3N	3O	2J3KL
1977			10.46	0.11				
1978	3.81	3.33	6.23	4.75				
1979	3.18	4.67	5.15	4.02				
1980			7.37	3.23				
1981	4.48	4.69	5.18	2.61	1.20			**8.99**
1982			5.88	2.34	1.32			**9.54**
1983			4.97	2.42	1.03			**8.42**
1984			4.59	2.59	1.26			**8.44**
1985			2.73	2.29	1.20			**6.23**
1986			2.54	0.83	0.90			**4.26**
1987	0.23	0.35	1.22	1.30	0.38			**2.91**
1988	0.16	0.18	1.27	1.06	1.00			**3.34**
1989			0.73	0.61	0.48			**1.82**
1990			0.62	0.61	0.34	0.00	0.00	**1.57**
1991	0.00	0.00	0.12	0.32	0.24	0.04	0.00	**0.68**
1992			0.07	0.10	0.16	0.04	0.00	**0.33**
1993			0.04	0.05	0.06	0.06	0.05	**0.14**
1994			0.03	0.08	0.10	0.10	0.02	**0.21**
Research Gear Change								

YEAR	ABUNDANCE INDEX (MILLIONS)*							
	2G	2H	2J	3K	3L	3N	3O	2J3KL
1995			0.00	0.12	0.10	0.21	0.13	**0.22**
1996	0.00	0.05	0.18	0.28	0.55	0.09	0.02	**1.00**
1997	0.07	0.01	0.33	0.30	0.35	0.28	0.04	**0.99**
1998	0.06	0.01	0.18	0.42	0.39	0.32	0.12	**1.00**
1999	0.04	0.18	0.14	0.64	0.48	0.19	0.03	**1.26**
2000			0.29	0.38	0.28	0.18	0.03	**0.95**
2001		0.00	0.12	0.46	0.26	0.26	0.03	**0.84**
2002			0.11	0.18	0.44	0.27	0.08	**0.73**
2003			0.10	0.08	0.22	0.16	0.04	**0.40**
2004		0.13	0.25	0.85	0.09	0.10	0.03	**1.19**
2005			0.61	0.76	0.49	0.21	0.12	**1.86**
2006		0.17	0.46	0.83	1.24	0.20	0.02	**2.53**
2007			0.74	1.34	0.62	0.37	0.16	**2.70**
2008		0.15	0.68	0.70	0.72	0.20	0.09	**2.11**
2009			0.70	0.64	0.52	0.40	0.04	**1.86**

*Blanks indicate that no survey was conducted.

Table 6. Rates of change in Northern Wolffish abundance indices based on research trawl survey data.

Survey	NAFO Divisions	Period	Total/Mature	Rate of change (%)	Natural log regression parameters			
					N years	R2	P-values	slope
Newfoundland & Labrador Fall Survey	2J3KL	1981-1994	Total	-99	13	0.910	<0.001	-0.33
		1995-2009	Total	324	14	0.471	0.005	0.07
Newfoundland & Labrador Spring Survey	3LNOPs	1971-1982	Total	4708	10	0.6657	0.004	0.34
		1984-1995	Total	-71	10	0.1147	0.308	-0.04
		1996-2010	Total	35	14	0.0318	0.542	0.02
			Mature	77	8	0.0733	0.516	0.07

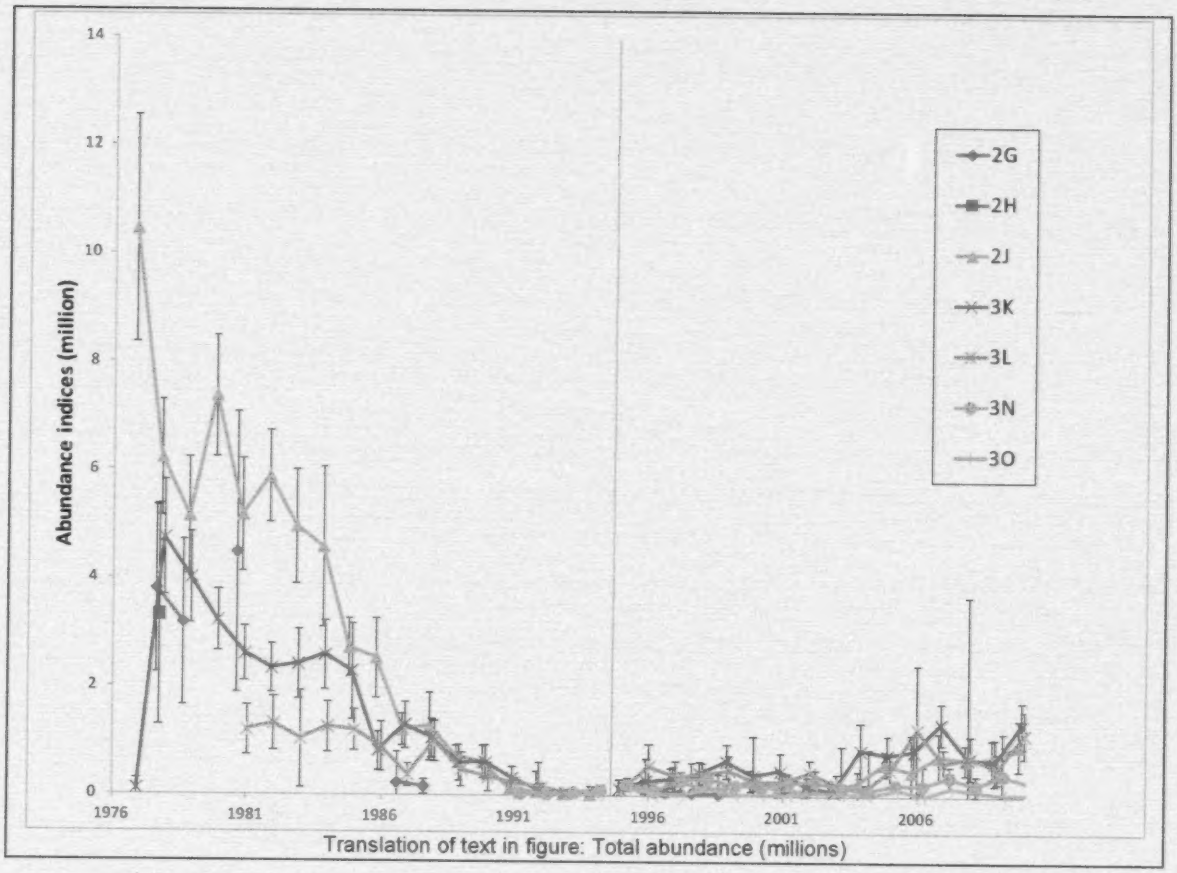


Figure 10. Northern Wolffish abundance (± CI) estimates based on Newfoundland and Labrador fall research trawl surveys for each NAFO Division covered. The vertical line indicates a gear change. Source: Simpson *et al.* (2011).

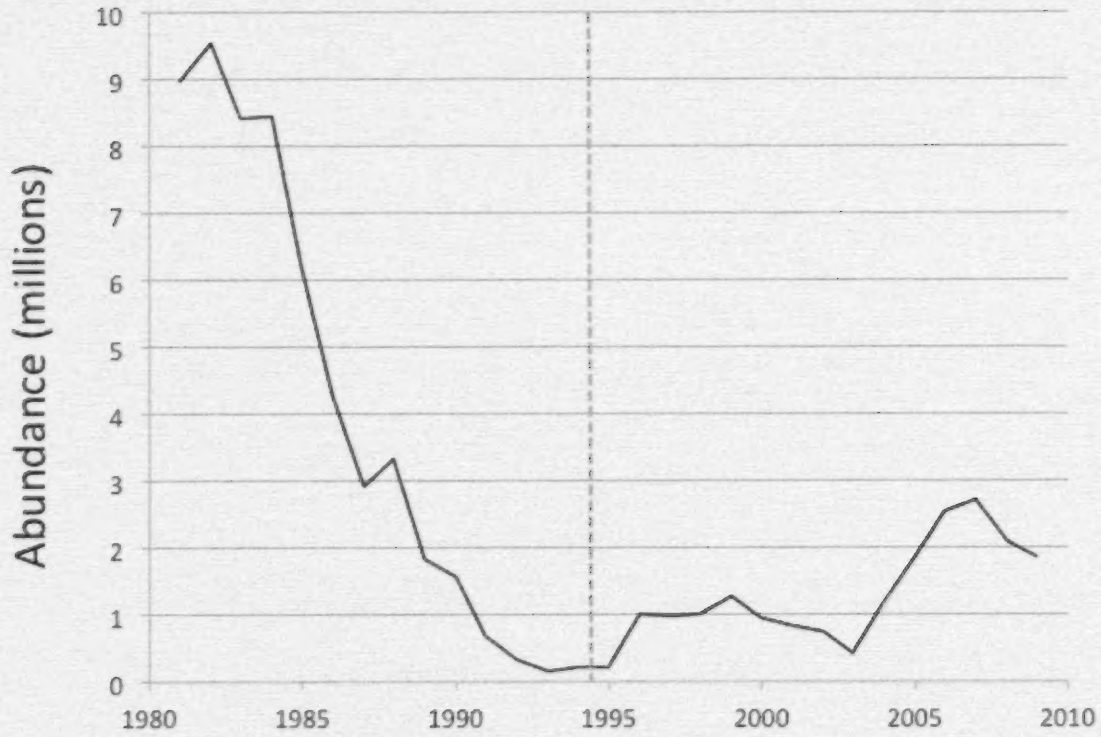


Figure 11. Northern Wolffish abundance estimates based on Newfoundland and Labrador fall research trawl surveys for NAFO Divisions 2J3KL from 1981 to 2009. The vertical line indicates a change in survey gear. Source: Mark Simpson, pers. comm., 2010.

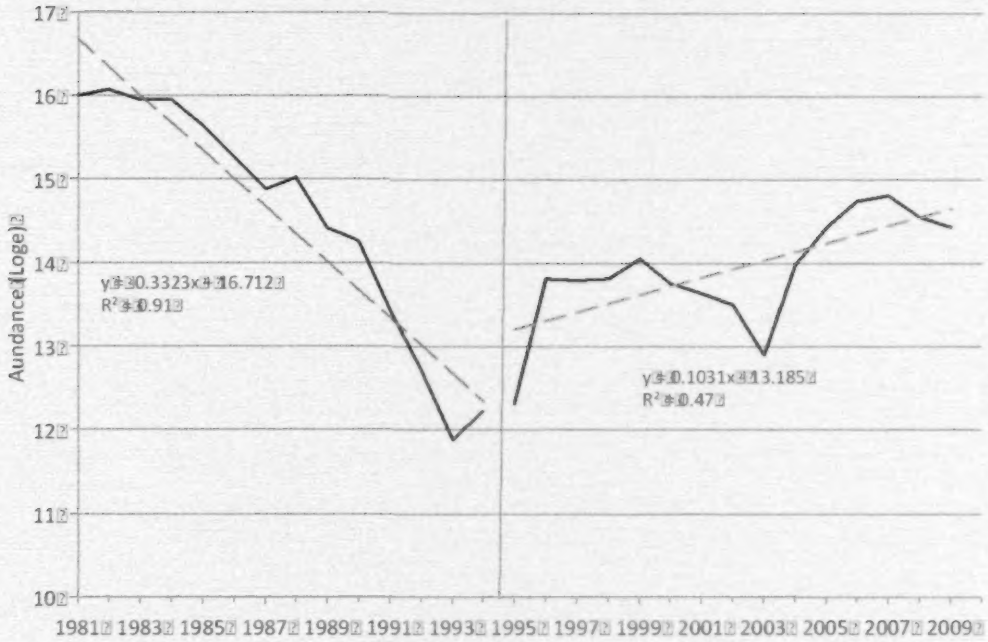
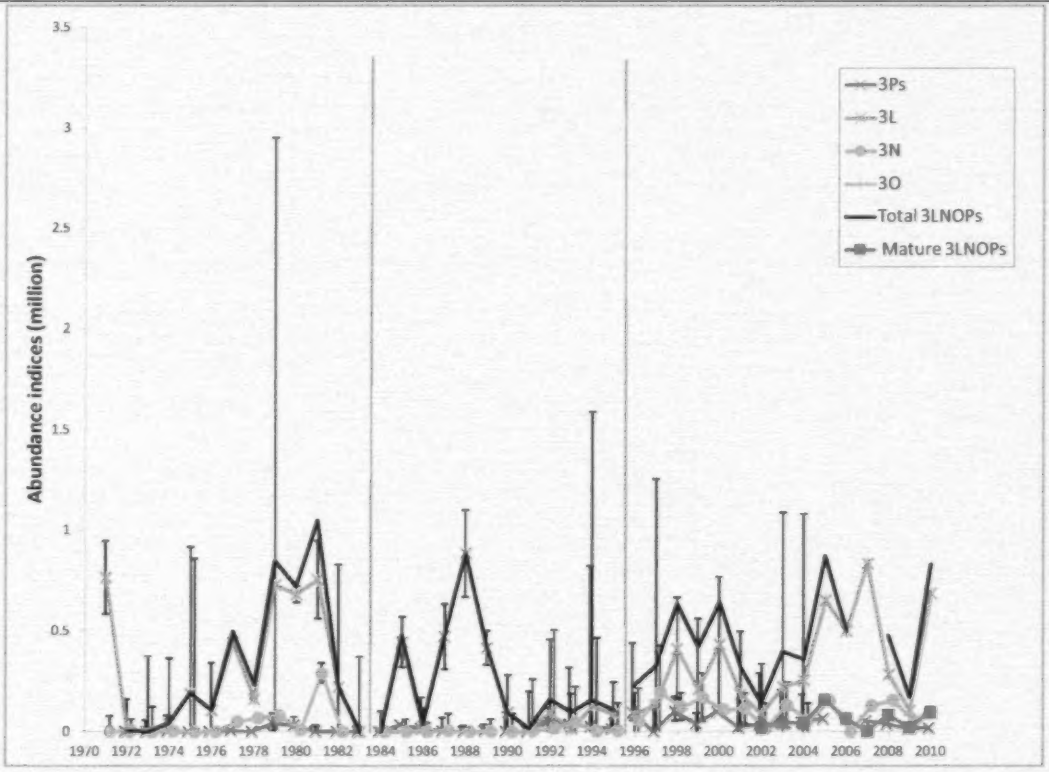


Figure 12. Estimate of $\log_e$ abundance of Northern Wolffish based on Newfoundland and Labrador Fall research trawl surveys in NAFO Divisions 2J3KL from 1981 to 2009. The vertical line indicates a change in survey gear.

When the surveys were initiated in the more southern areas (eastern Newfoundland and Newfoundland Grand Banks, NAFO Divisions 3LNO), abundance was already low in the more northern areas. The values obtained in recent years off eastern Newfoundland and on the Newfoundland Grand Banks are similar to those obtained in the mid-1990s. Moreover, the abundance estimates in the area to the south (3NO) are lower and more variable than those recorded in areas to the north (2J3KL) (Table 5 and Figure 10).

In spring trawl surveys on the Grand Banks (Divisions 3LNOPs), most catches come from NAFO Division 3L (northern Newfoundland Grand Banks), indicating that areas south of Div. 3L are at the southern fringe of the distribution. Note that the Labrador Sea, where abundance is concentrated based on fall surveys, is not surveyed in the spring. The three spring data series (1971 to 1982, 1984 to 1995 and 1996 to present) cannot be compared directly due to the change in gear.

Abundance on the Grand Banks increased from 1971 to 1981 (Figure 13), followed by strong variation from year to year over the 1980s and early 1990s. Although the rate of increase in the 1970s appeared to be 4,708% (Table 6, Figure 14), this large value is caused by the low abundance in the first year and the high variability in the indices of abundance, and should not be taken literally. The total abundance indices ranged from 0.03 to 0.91 million between 1984 and 1995 (Table 7). This variability could be caused by the low abundance and therefore low catch rates in this area for this species. Since then, abundance has continued to fluctuate, but values in several recent years are among the highest since the start of the series in 1996. Indices of the total population over 0.8 million have been recorded in three of the last five years, where the maximum value between 1996 and 2004 was 0.7 million (Table 7 and Figure 13). Thus, it appears that Northern Wolffish are in relatively low abundance on the southern Grand Banks in Divisions 3NO and their abundance has fluctuated without trend since the 1980s. (Table 6).



Translation of text in figure: Total abundance (millions)

Notes: Vertical blue lines indicate a vessel and gear change. The "total" line indicates the sum of the abundances for all Divisions only when all Divisions were surveyed. Abundance of matures is based on the proportion of fish ≥ 73.0 cm in Newfoundland & Labrador fall and spring research trawl survey catches each year.

Figure 13. Northern Wolffish abundance estimates (± CI) from the Grand Banks, based on Newfoundland and Labrador spring research trawl surveys for each NAFO Division covered from 1971 to 2010. The vertical lines indicate changes in survey gear. Note that there was an incomplete survey in 1983.

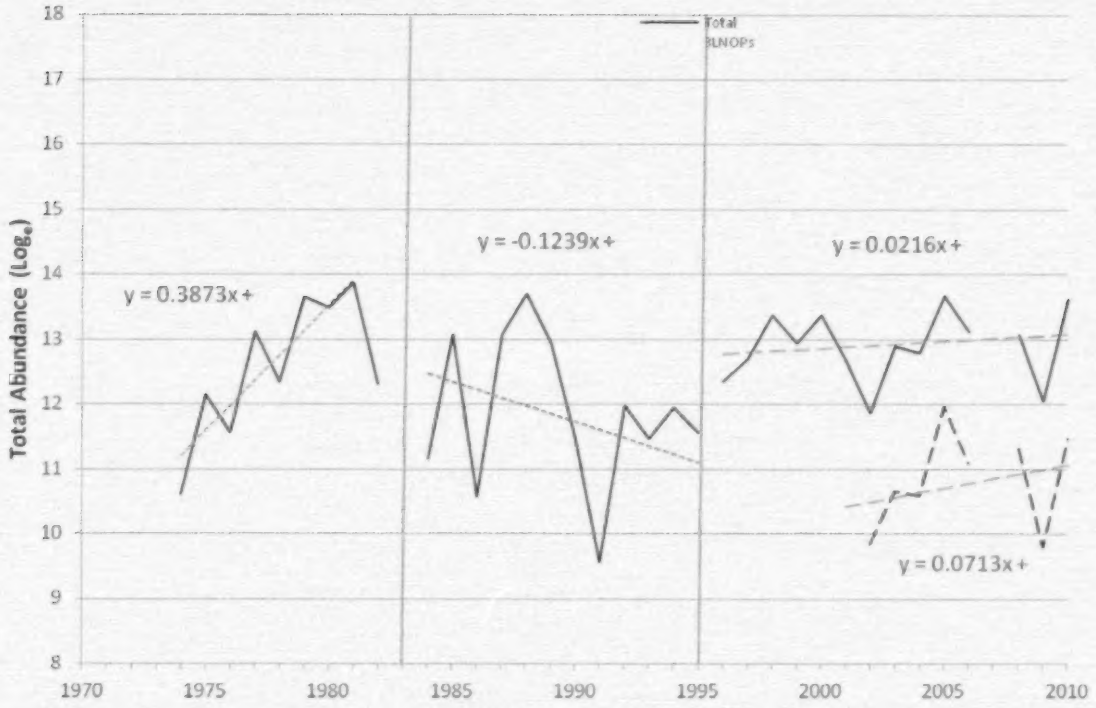


Figure 14. Estimates of $\log_e$ abundance of Northern Wolffish based on Newfoundland & Labrador Spring research trawl surveys in NAFO Divisions 3LNOPs. The vertical lines indicate a change in survey gear.

Table 7. Northern Wolffish abundance indices based on Newfoundland & Labrador spring research trawl survey data.

YEAR	ABUNDANCE INDEX (MILLIONS)*				
	3L	3N	3O	3Ps	Total
1971	0.76	0.00			
1972	0.00	0.01		0.03	
1973	0.00	0.00	0.00	0.02	**0.02**
1974	0.04	0.00		0.01	**0.05**
1975	0.19	0.00	0.00	0.06	**0.25**
1976	0.11	0.00	0.00	0.32	**0.43**
1977	0.44	0.05	0.00	0.04	**0.53**
1978	0.16	0.07	0.00	0.08	**0.31**
1979	0.73	0.08	0.04	0.06	**0.91**
1980	0.68	0.01	0.03	0.01	**0.73**
1981	0.75	0.29	0.00	0.02	**1.07**
1982	0.22	0.00	0.00	0.13	**0.35**
1983	**Research Gear Change**				
1984	0.00	0.00	0.00	0.07	**0.07**
1985	0.44	0.00	0.03	0.09	**0.57**
1986	0.03	0.00	0.01	0.02	**0.06**
1987	0.47	0.00	0.00	0.06	**0.54**
1988	0.88	0.00	0.00	0.03	**0.91**

YEAR	ABUNDANCE INDEX (MILLIONS)*				
	3L	3N	3O	3Ps	Total
1989	0.41	0.00	0.00	0.07	**0.49**
1990	0.10	0.00	0.00	0.05	**0.15**
1991	0.01	0.00	0.00	0.02	**0.03**
1992	0.09	0.02	0.05	0.03	**0.19**
1993	0.01	0.05	0.04	0.03	**0.13**
1994	0.13	0.00	0.02	0.02	**0.18**
1995	0.09	0.00	0.01	0.07	**0.18**
Research Gear Change					
1996	0.09	0.05	0.09	0.13	**0.36**
1997	0.13	0.19	0.00	0.00	**0.33**
1998	0.41	0.12	0.10	0.06	**0.70**
1999	0.21	0.17	0.04	0.10	**0.52**
2000	0.43	0.11	0.10	0.00	**0.64**
2001	0.19	0.11	0.02	0.02	**0.33**
2002	0.09	0.02	0.04	0.02	**0.16**
2003	0.22	0.13	0.04	0.09	**0.49**
2004	0.25	0.06	0.05	0.00	**0.36**
2005	0.65	0.15	0.06	0.06	**0.93**
2006	0.50	0.00	0.00		
2007	0.83	0.13	0.05	0.01	**1.03**
2008	0.28	0.16	0.04	0.08	**0.55**
2009	0.11	0.05	0.01	0.04	**0.21**
2010	0.69	0.12	0.02	0.03	**0.85**

*Blanks indicate that no survey was conducted.

Other areas (Gulf of St. Lawrence, Scotian Shelf, Arctic)

In the Gulf of St. Lawrence, Northern Wolffish rarely appears in DFO research trawl surveys. Only three specimens have been caught in the Northern Gulf survey since 1990 (Johanne G. pers. com. 2012). Therefore, the change in abundance is presented as a function of relative occurrence in the northern Gulf and southern Gulf research surveys (number of tows in which the species is present/total number of tows). Note that the spatial coverage of the surveys has varied over the years. Prior to the start of the northern Gulf survey (1984), only a few deepwater strata in the Esquiman Channel were surveyed in the northern Gulf (as part of the southern Gulf survey). In NAFO Division 4T, Northern Wolffish has been captured only in 13 years out 40 in the Southern Gulf Reasearch Survey conducted from 1971 to 2010 (Benoit, H. pers. com. 2012).

The occurrence of Northern Wolffish in the Northern Gulf varies depending on the period analyzed. The highest occurrences were observed in the late 1970s and early 1980s (Figure 15). The frequency of occurrence of the species before and after that period is low.

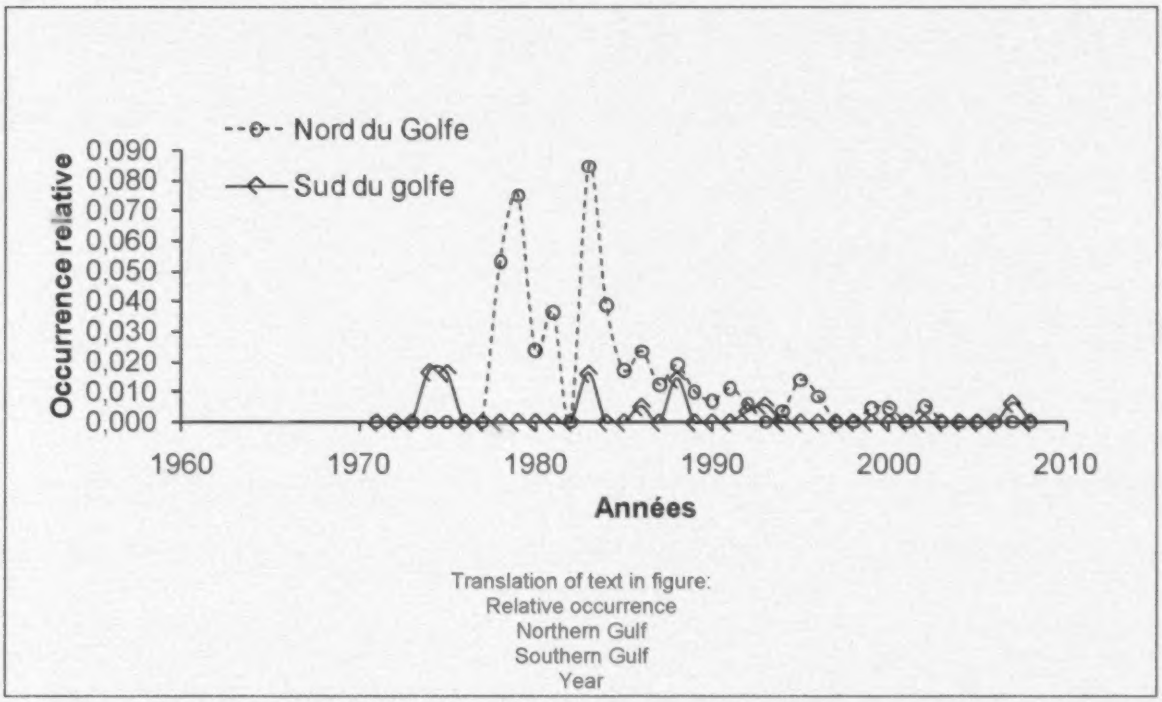


Figure 15. Relative occurrence (number of tows in which the species is present/total number of tows) of Northern Wolffish (all ages combined) in research trawl surveys in the northern and southern Gulf of St. Lawrence (NAFO Divisions 4RST).

The Northern Wolffish is also very rare in the southern part of its Canadian range. In the Maritimes summer research trawl survey on the Scotian Shelf (Divisions 4VWX), this species has been caught in only 30 of 7,200 tows since 1970, preventing an assessment of trends. Most fish were captured along the outer shelf at the edge of the survey, suggesting they may be deeper than the survey footprint. The Scotian Shelf survey fishes only to about 350 m, which is considerably shallower than the preferred depth range of this species.

From six surveys in Arctic waters (NAFO Divisions 0A and 0B), only 10 Northern Wolffish have been caught.

Summary for Canada

These fish underwent severe declines in abundance during the 1970s and 1980s. For the next decade there was little change in status, but since about 2002 there have been small increases in many areas. Differences among regions in survey methods and changes in gear over time preclude formal calculations of an overall trend for this species in Canada. However, a general indication is needed to assess this species' overall status. The following back-of-the-envelope calculations are for the total number of fish.

The southern Labrador Shelf (2J3KL) was and is the historical stronghold, with about 9 million individuals, representing about 97% of the total fish in the surveys. They declined by about 99% from the early 1980s until the gear change in the mid1990s (Table 6). The remaining 1% of fish then increased to about 4% of the original numbers. Some of this apparent increase may have been driven by the higher catchability of the new gear, though the multiplication of the percent remaining prior to the gear change by the trend after the gear change partially accounts for this. Taken together, the overall decline is about 96%. Factoring in fish from the Grand Banks (3LNOPs) makes little difference to the estimate of overall trends, due to their very low numbers at the start of the time series. The estimate of 96% must not be taken literally: it is from approximations intended only to give a general impression of the magnitude of decline relative to the ranges that are used by IUCN criteria.

Rescue Effect

The range of the Northern Wolffish extends outside Canadian waters. This species is distributed across the following areas:

- to the south, in the Gulf of Maine and on Georges Bank (very rare);
- to the north, off West Greenland; and
- to the east, in several NAFO Divisions that are partially (Divisions 3LNO) or entirely (3M) located in international waters (see Figure 2).

There is no biological or physical rationale for differentiating between the populations on either side of the Canadian international boundary. The fish are very rare in the Gulf of Maine (United States), so rescue from south of the border is unlikely. In the northern part of its range, off West Greenland, little information is available on abundance.

On the basis of surveys by the Instituto Español de Oceanografía [Spanish Institute of Oceanography] (Gonzáles-Troncoso and Paz 2007), Northern Wolffish abundance on the Flemish Cap (NAFO Division 3M) was estimated at close to 0.9 million in 2006. The abundance index appears to have increased in recent years (Figure 16). Abundance off West Greenland is poorly known. Rescue from the east therefore seems possible.

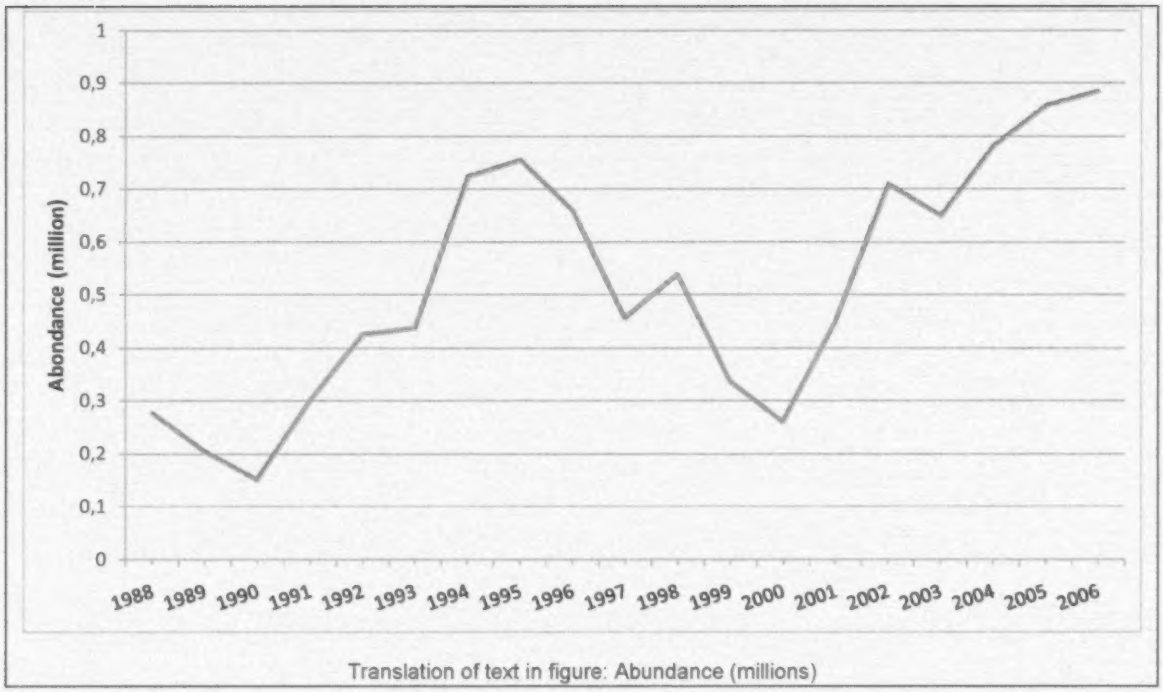


Figure 16. Northern Wolffish abundance estimates (all ages combined) for the Flemish Cap (NAFO Division 3M) based on research trawl surveys conducted by the Instituto Español de Oceanografía (Spanish Institute of Oceanography). Source: Based on Gonzalez-Troncoso and Paz (2007).

THREATS AND LIMITING FACTORS

Commercial Fishery and Bycatch

Fishing was identified as the main cause of the decline of wolffish species (O'Dea and Haedrich 2001). Prior to the implementation of the mandatory release policy for threatened wolffish species in 2003 under the *Species at Risk Act*, there were no regulations governing wolffish fishing effort or catch levels. Northern Wolffish is caught solely as bycatch. The three species are not differentiated in catch statistics, making it difficult to assess fishing mortality.

As reported by Simpson and Kulka (2002) and based on fishery observer records, virtually all bycatch of Northern Wolffish was discarded prior to 2003. This continues to be the case as they are of no commercial value and release is mandatory under the *Species at Risk Act*. Experiments with Atlantic Wolffish indicate survival is high if released soon after capture from shallow waters (Grant *et al.* 2005). However, survival from the deeper waters often inhabited by Northern Wolffish is probably lower. Fishing intensity is now much lower due to the closure of many groundfish fisheries, though fishing mortality rates for this species are unknown. Because their distributions include deeper waters than the other two wolffishes, they are exposed to greater bycatch from fisheres such as those targeting snow crab and Greenland Halibut (*Reinhardtius*

hippoglossoides). A study of bycatch in Shrimp Fishing Areas 0-3 (from east of Baffin Island to the waters around the Ungava Peninsula) shows very little bycatch of this species, with 0.1-7 % of sets catching one or more individuals, depending on the area and year (Silferd 2010). Wolffish are also taken outside Canadian waters as bycatch in fisheries regulated by NAFO.

An analysis by Kulka *et al.* (2004) of the potential role of fisheries on the decline of wolffish populations has argued that neither bycatch nor the destruction of bottoms has been the primary cause of the decline of the three wolffish species. They suggested that the decline of Northern Wolffish was as great or greater in unfished areas compared to heavily fished locations, implicating factors in addition to fishing pressure. Disturbance or alteration of ocean bottoms by repeated use of mobile gear (primarily bottom trawls and dredges) could also pose a threat, though the extent is unknown.

Environmental Factors

A period of exceptionally cold water temperatures from the late 1980s to 1990 (Colbourne *et al.* 2004) matched the latter half of the period of decline of wolffish species, although no direct causal relationship has been established. Kulka *et al.* (2004) showed that Northern Wolffish seek specific temperatures and as such, cooling conditions could potentially affect the population.

Climate change could affect the distribution and abundance of Northern Wolffish due to changes in marine ecosystems. It is expected that temperature increases will become more pronounced in northern areas, where this species is found (Trenberth *et al.* 2007). Movements will be mostly towards the poles, increasing the range of warm-water species and decreasing the range of cold-water species (Perry *et al.* 2005, Cochrane *et al.* 2009). The distribution of boreal and subarctic species, such as wolffish, could therefore shift northward (Gucinski *et al.* 1990).

Number of Locations

Following IUCN guidelines, COSEWIC defines the number of locations according to the threats. Based on the threat of bycatch in fisheries, this species can be considered to occupy a large number of locations, as different fisheries occur across a wide geographic area and are managed separately.

PROTECTION, STATUS AND RANKS

Legal Status and Protection

The Northern Wolffish was first designated Threatened by COSEWIC in May 2001, the status was confirmed in 2012 and the species has been protected under the federal *Species at Risk Act* (SARA) since 2003. Under an amendment to the federal *Fisheries Act* that will probably take effect in 2013, destruction of fish habitats will no longer be prohibited unless the species is subject to fisheries. As there are no fisheries for Northern Wolffish, their habitats may no longer be protected by the *Fisheries Act* unless the habitats are shared with other species targeted by fisheries. The definition of wolffish habitat is unclear; they are found over a variety of habitats.

In accordance with the Recovery Strategy for the Northern Wolffish, fishers authorized under the *Fisheries Act* who are engaged in commercial or recreational fishing or in a First Nation's food, social and ceremonial (FSC) fishery for groundfish, shellfish and pelagic species (including emerging fisheries) are permitted to carry out commercial fishing activities that may incidentally kill, harm, harass, capture or take the Northern Wolffish as per subsection 83(4) for the *Species At Risk Act*. Specifically, the licence holder/operator is required to ensure that, while the fishing activities are conducted, all Northern Wolffish caught incidentally are returned to the place from which they was taken, and if they are alive, in a manner that causes the least harm. In addition, information with regard to interactions; position (latitude and longitude) at time of catch; quantity; weight; and, condition (dead/alive) must be recorded in logbooks.

The Northern Wolffish is listed as likely to be designated threatened or vulnerable under Quebec's *Act Respecting Threatened or Vulnerable Species* (Loi sur les espèces menacées ou vulnérables; R.S.Q., c E-12.01). There is no mention of this species in the CITES appendices or in the United States *Endangered Species Act*.

Non-Legal Status and Ranks

The species has not been ranked at the global or Canadian level by NatureServe, and is listed as between Vulnerable and Apparently Secure (S3S4) by Quebec. It has not been assessed by the International Union for the Conservation of Nature (IUCN).

Habitat Protection and Ownership

In the Canadian portion of the northwest Atlantic there are five small marine protected areas as well as a few other areas closed to trawling. However, the area of protection for Northern Wolffish is very small compared to its widespread distribution and habitat requirements. The effects of these closures on wolffish are unknown, and their overall impacts on the population are apt to be minimal.

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